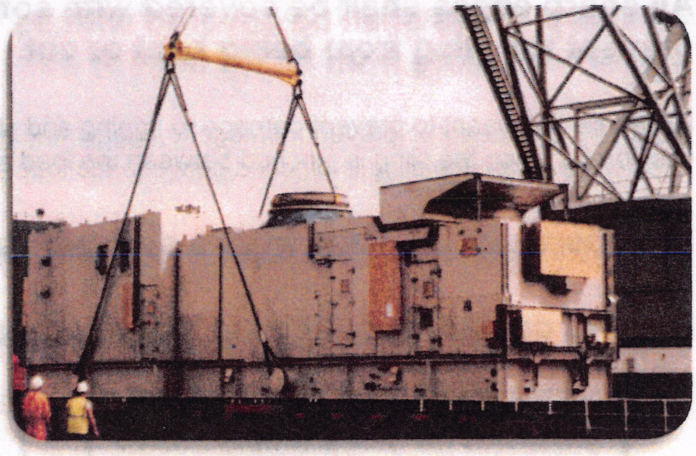
Module 11
Rigging Principles



Learning Objectives

By the end of this section, you will:

1. Know how to rig a load for a lift.
2. Know rigging terminology and nomenclature.
3. Select appropriate slings and rigging hardware for rigging tasks.
4. Understand the importance of balancing the load when using a bridle hitch.
5. Apply safe work practices when performing rigging operations.
6. Know the factors affecting rigging capacity.
7. Know how to calculate the sling angle.
8. Know how to calculate sling stress for a choker hitch.
9. Know how to calculate the tension on sling legs of a symmetrical load.
10. Inspect slings as described in ASME B30.9.

Preparing the Load

The main considerations when preparing a lift are:

1. **Weight.**
2. **Size.**
3. **Center of gravity of the object being lifted.**
4. **Path and load placement of object being lifted.**

Slings

The safe use of slings, which requires staying within their rated capacity, depends on 4 important factors:

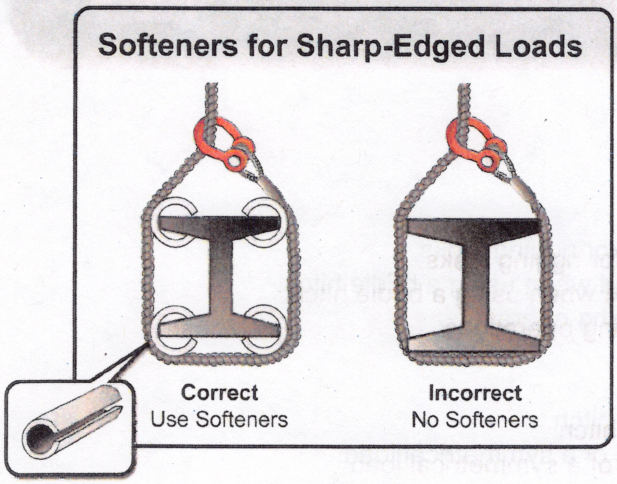
- The size of the sling.
- The hitch in which the sling is configured.
- The angle of the sling.
- The sharpness of the edges of the load which the sling passes around.

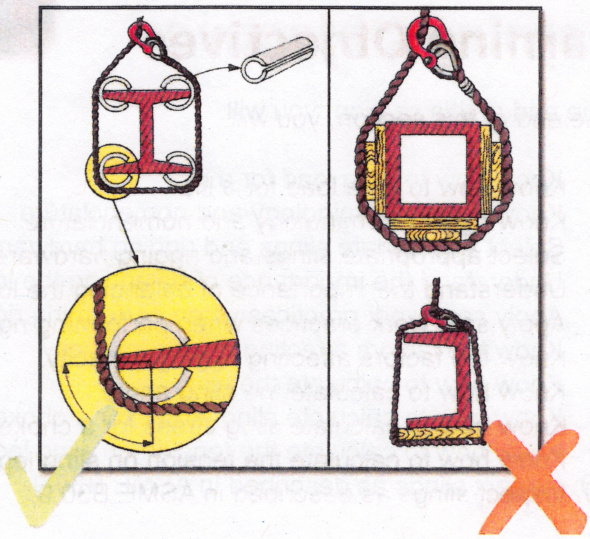
All sharp edges shall be covered with softeners for one lay length to prevent the sling from being bent or cut.

Softeners are meant to prevent damage to rigging and slings from sharp edges. They also act as a cushion for when the sling is pinched between the load and surfaces.

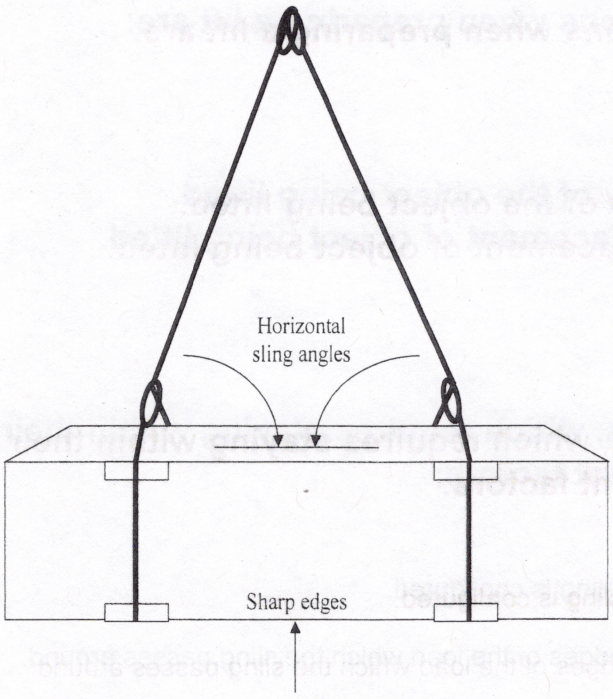
Softeners can be made from a split pipe section, padding or blocking.

Point of contact should be at least 7 times the rope diameter for a softener.

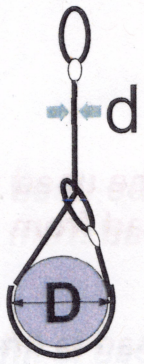




The method in which a sling is rigged or attached to a load is referred to as a "hitch."

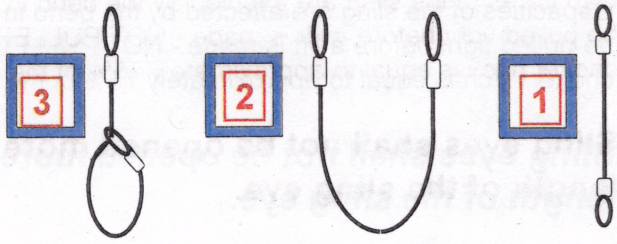


D/d ratio is the ratio of the diameter of the load to the diameter of the sling.



There are 3 basic hitches. Identify them below.

1. **Single vertical hitch.**
2. **Basket hitch.**
3. **Choker hitch.**

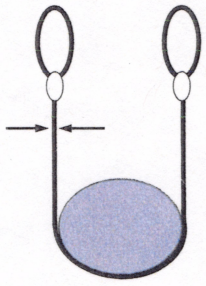


#1

A STRAIGHT or vertical hitch is simply using a sling to connect a lifting hook to a load. Full rated lifting capacity of the sling may be utilized, but must not be exceeded. A straight hitch is equal to 100% of the ropes capacity.

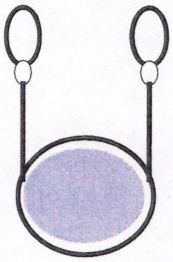
#2

A BASKET hitch distributes a load equally between the two legs of the sling.



A basket hitch is equal to 200% of the ropes capacity if the D/d ratio is greater than 25:1. Capacity of a basket hitch is affected by the bend (D/d ratio) where the sling body comes in contact with the load. Each of the vertical legs should be less than 5° from vertical or it must be considered a bridle.

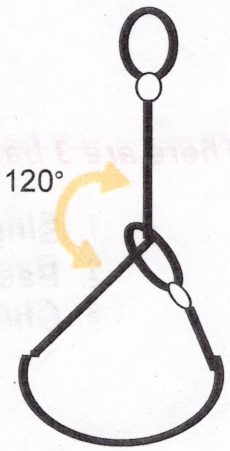
A double wrap basket hitch will not increase the capacity of the sling.



It should be used to keep a loose load from slipping

#3

A CHOKER hitch tightens as the load is lifted due to the noose formed at the point of choke.



Capacities of the sling are affected by the bend in the sling. A choker hitch should be pulled tight before a lift is made - NOT PULLED DOWN DURING THE LIFT. A choker hitch is equal to approximately 75% of the ropes working load limit.

Sling eyes shall not be opened more than 50% or 1/2 the length of the sling eye.

Slings are continually subjected to abnormal abuse due to overloading, abrasion, crushing, kinking, and impact loading. Extra stress is often put on chokers when the sling angle is increased to unacceptable levels.

OSHA 1926.251 (c)(1) sets the minimum safety factor for wire rope slings to be no less than 5 to 1.

- (c)(13)(i) Wire rope slings shall have a minimum clear length of ten rope diameters between splices, sleeves or end fittings.
- (c)(13)(ii) Braided slings shall have a clear length of wire rope 40 times the component rope diameter between splices, sleeves, or end fittings.

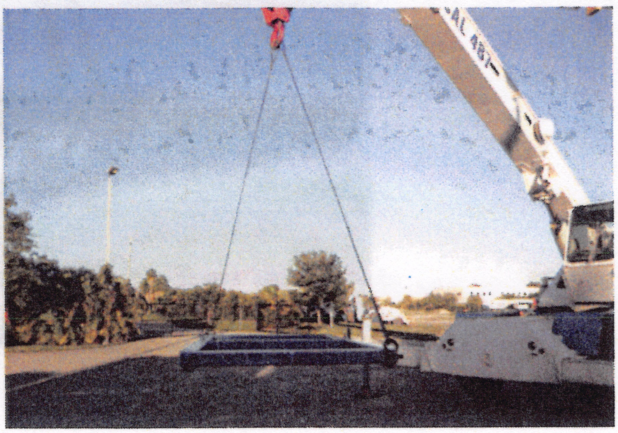
Hitches and Bridles

A single vertical hitch supports the entire weight of load with a single sling.

A single vertical hitch is the most common type of rigging.

A bridle hitch can be made from two or more legs, but typically 2, 3, or 4.

The more legs, the better support if rigged correctly. A two leg hitch is most typical set up because it is a straight forward rig. Non-symmetrical load cause bridle hitch to have legs of varying length and angles along with hitch points at different elevations. These make calculations difficult. Smallest L/H ratio should be used.

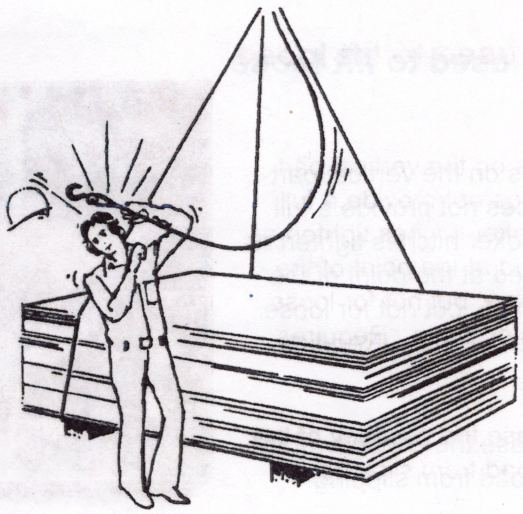


Bridles with three legs will result in uneven sling leg loading if not properly hooked.

On symmetrical loads, pick up points must be evenly spaced or load will primarily be on two legs with the third acting as a balance. When using 3 or 4 leg slings, ensure load is equalized on each leg. Improper rigging could result in two legs primarily carrying the load while third and fourth acts as a balance. Therefore, smallest L/H ratio should be used when legs are not equal.

Do not drag rope out from under a load.

OSHA 1926.251(c)(12)

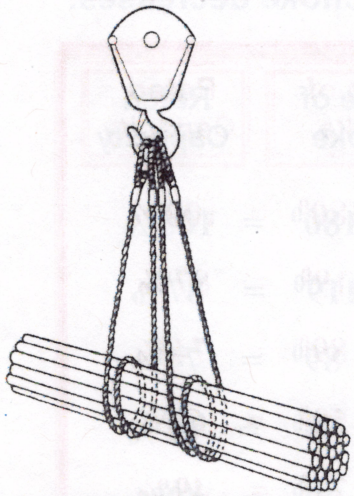


Basket Hitches

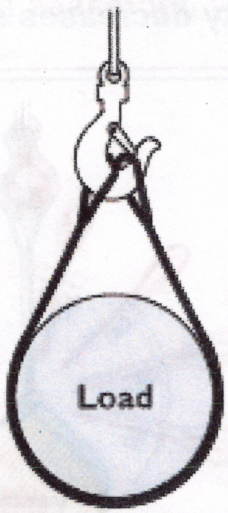
Single wrap & double wrap basket hitches use a sling that is wrapped around the load with both ends secured to a hook.

Double wrap basket hitches are often used for bundle-type loads. Single wrap basket hitches are not recommended for loads that are difficult to balance. Caution should be exercised not to spread legs too far apart.

Double wrap basket hitch is wrapped completely around load with both ends secured to hook.



Double wrap basket hitch

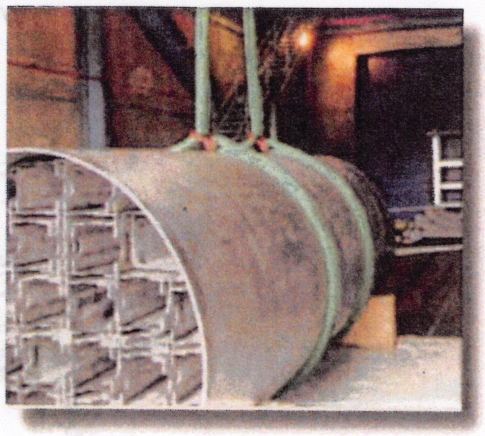


Single wrap basket hitch

Very secure hitch. Hitch exerts full 360 degrees of contact and pulls load together. Excellent hitch for pipes and tubes. A full basket hitch is rated at 200% of a single vertical hitch.

Choker Hitches

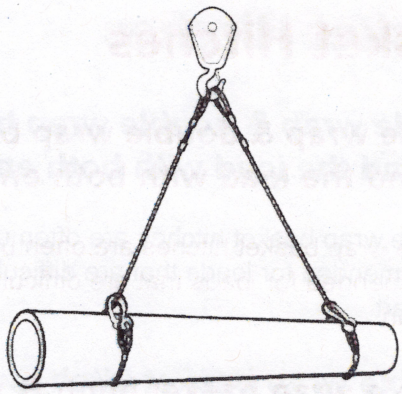
Two choker hitches should be used to lift loose bundles.



Heavy loads produce extreme point stress on the vertical part of the hitch. A single wrap choker hitch does not provide a full 360 degrees of contact with the load. Choker hitches tighten as the load is lifted because a noose is formed at the point of the choke. Great for loads such as a single pipe, but not for loose bundle loads such a reinforcing bar, pipes or tubes. Requires balancing the load.

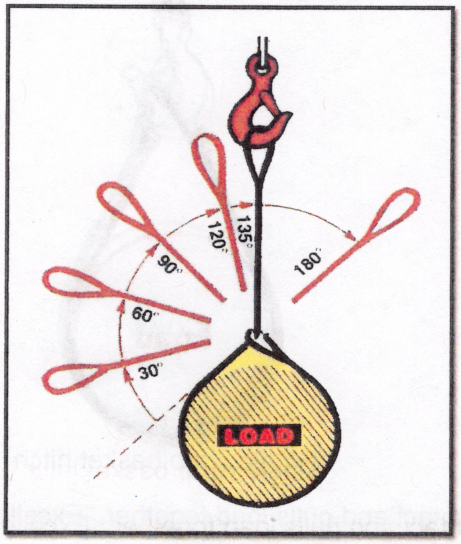
A double wrap choker hitch will not increase the capacity of the sling. It should be used to keep a loose load from slipping.

Double choker hitches are made by using two single chokers that are spread apart on the load.



Caution should be exercised not to spread legs to a horizontal angle less than 45 degrees. The choker hitch makes a much more stable load. Hooks are pointed out to prevent accidental unhooking and load loss. A double wrap choker hitch provides a full a 360 degree wrap around load prior to being choked to vertical part of sling. Double wrap choker hitches are well suited for lifting loose bundles. Also causes hitch to cinch up on the load when tension is applied.

Rated capacity decreases as the angle of the choke decreases.



Angle of Choke	Rated Capacity
120^0 - 180^0	= 100%
90^0 - 119^0	= 87%
60^0 - 89^0	= 74%
30^0 - 59^0	= 62%
0^0 - 29^0	= 49%

Synthetic Slings

Synthetic rounds lings are light and flexible.

Synthetic rounds lings load carrying fibers are covered with a colored non-load carrying jacket.

The cover helps protect the sling but don't trust the color - always look at the tag for capacity. Sling characteristics are regulated by ANSI B30.9.

- Synthetic web slings are typically made of nylon.
- Flexible flat slings hold loads more secure and prevents material slippage during handling.
- As with any other crane or rigging component, slings will only be effective if maintained properly.
- Working temperature range varies with sling material.
- Manufacturers can provide information for specific slings that can be used with hazardous products.

Lifts depend on slings, so attention must be paid to their maintenance.

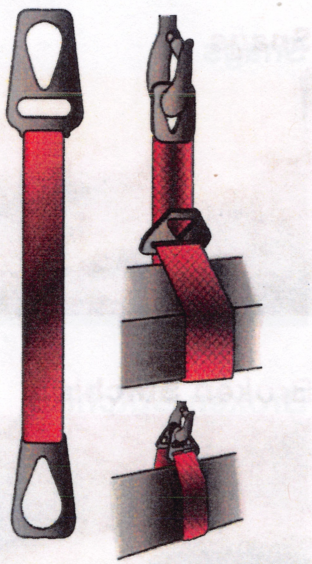
OSHA®

1926.251(a)(1)
1926.251(a)(6)
1926.251(e)(7)

Damaged slings must be removed from service.

Strength is only guaranteed when the sling is in perfect working condition. They can be affected by:

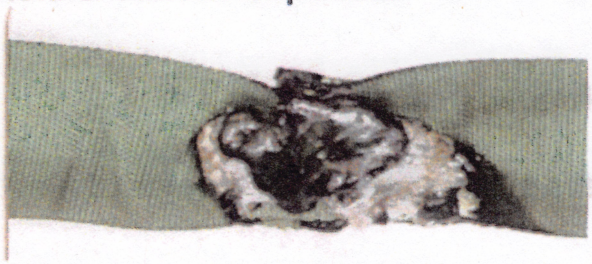
- Acid or caustic burns.
- Surface part melting or charring.
- Snags.
- Punctures.
- Tears or cuts.
- Broken stitches.
- Distorted fittings.
- Overloading.
- Abrasion.
- Crushing.
- Kinking.
- Impact loading.

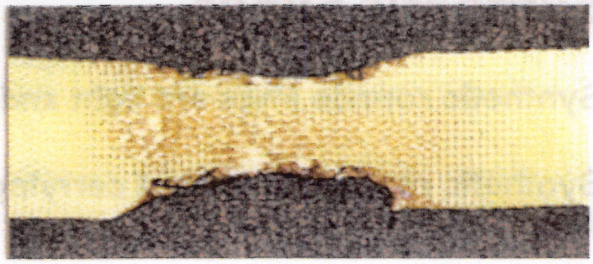


Many braided slings provide exceptional strength and flexibility, are nearly impossible to kink and are used in high capacity lifts.

For synthetic slings eyes must not be open more than 1/3 the eye length.

Acid & caustic exposure



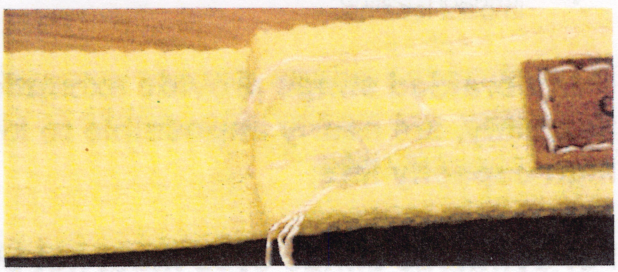


Melting and Charring

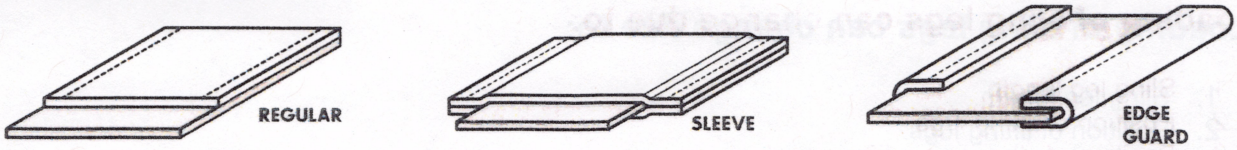
Cuts

Snags

Broken Stitching



Edge protectors are designed to prevent damage to synthetic webbing.



Many different eye configurations are available: Sewn in, sliding, replaceable.

The effects of shock loading are magnified in sling legs.

Shock loading is typically caused by carelessness or accidents.

1. Rapid lowering and sudden stopping.
2. Load sticking and suddenly coming loose.

Shock loading is a stress that can not be calculated, but should be expected. For this reason, equipment should be in perfect working condition. Equipment exposed to shock loading should be closely inspected for damage and replaced if safe working capacity can not be assured. Always refer to sling chart for proper sling size to match load and hook up configuration. Lower horizontal sling angles are more effected by shock loading.

What is the stretch difference between nylon and polyester web slings?

» At rated capacity, a nylon sling stretches approximately 8 to 10%, whereas a polyester sling will stretch approximately 3%.

» Nylon's extra stretch helps to avoid shock loading.

What about chemical resistance?

» Polyester is resistant to acids; nylon is better for aldehydes.

	Nylon	Polyester
Acids	**No**	Ok, except for sulfuric acid
Alcohols	Ok	Ok
Aldehydes	Ok	**No**
Strong Alkalis	Ok	Degradation at high temperatures
Bleaching Agents	**No**	Ok
Oils	Ok	Ok
Ethers	Ok	**No**
Soap & Detergents	Ok	Ok
Water & Sea Water	Ok	Ok

Chemical compatibility information courtesy Ashley Sling, Inc.

Synthetic slings made of nylon resist most alcohols, aldehydes, alkalis, hydrocarbons. Not recommended for use in applications around acids; use polyester slings instead. Nylon synthetic material well suited for many applications. Should never be used around caustic substances or extreme heat. Synthetic sling distributors can provide information for specific slings that can be used with chemicals and hazardous products.

Factors affecting rigging capacity

Loading of sling legs can change due to:

1. Sling leg length.
2. Position of lifting lugs.
3. Position of sling eye in lifting hook.
4. Twisted, warped, or uneven structure.

Calculations are based on symmetrical loads. The hook should be spotted over the center of gravity to avoid:

1. Changes of load distribution on slings.
2. Increasing stress on sling.
3. Causing the load to shift, tip or swing.

Non-symmetrical loads require a method of adjustment to be balanced to allow the hook to be centered over the load's center of gravity. For lighter loads the adjustment method can be a turnbuckle, a come-a-long, or a chain fall. Come-a-longs and chain falls are not recommended on heavier loads. Proper adjustments are not easy on come-a-longs and chain falls. A non-symmetrical load may cause the bridle hitch to have legs of varying length and angles along with attachment points at different elevations. These make calculations difficult.

Horizontal sling angle is critical to safe lift capacity! The higher the angle, the lower the stress on the sling.

Extra stress is placed on slings when horizontal sling angle is decreased to unacceptable levels.

Horizontal sling angle should be greater than 45 degrees whenever possible.

Sling angles approaching or less than 30 degrees present hazardous operating conditions and could result in equipment failure. Sling angle is the critical factor for calculating the safe working load (SWL) of a sling. SWL and stress are based on the angle formed between a leg and horizontal (the ground).

60 degrees is an easy angle to create since it forms an equilateral triangle.

Measure the angle between horizontal and the sling leg and, if the legs are of unequal length, use the smallest angle. Not an easy angle to figure out or measure.

1. Find the center of the load.
2. Lay the center of sling over the center of the load.
3. Mark the ends of the sling.
4. Rig the slings at the marks and pull loose ends together.

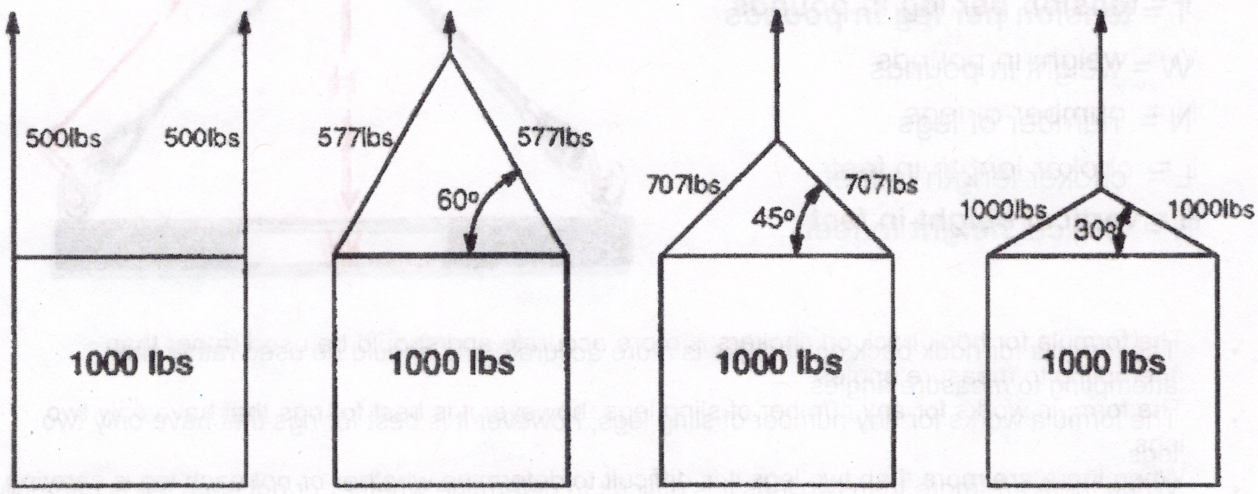
When sling legs are pulled together into a common hook, each leg will have an increased load.

Example:

- 60 degree leg angle = 115% load.
- 45 degree leg angle = 140% load.
- 30 degree leg angle = 200% load.

As the angle decreases from vertical (straight pull), the amount of sling tension increases.

Sling leg load increase may not be realized by person hooking the load. The rigger could incorrectly assume that each leg carried only 1/2 of load.



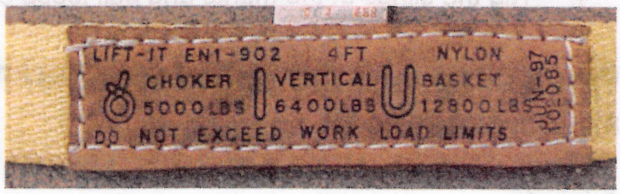
Calculating rigging capacity

The weight of the load can equal the safe working load (SWL) of the sling.

Safety factors vary and are not consistent between manufacturers and safety professionals.

Most OSHA regulations specify a minimum 5:1 rigging safety factor. Some load tables will list sling angles as low as 15 degrees, however an error of more than 50% can be made when calculating the assumed load on the sling.

Most sling charts and tables give three values: choker hitch, vertical hitch, basket hitch.



Sling chart values are important considerations Vertical hitch capacity is used as the basis for establishing capacities for basket and choker hitches. The rule of thumb for single ply synthetic web slings is a SWL of 1,600 lbs. per inch of width. It is not safe to assume that double ply ratings can carry twice the load of a single ply. Depending on sling type and hook up, double ply capacity ranges from 140% to 200% that of single ply.

The sling stress formula allows the use of a tape measure rather than working with angles:

$$T = (W/N) \times (L/H)$$

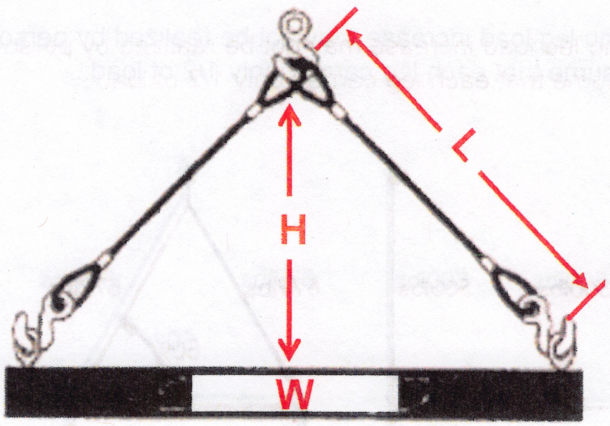
T = tension per leg in pounds

W = weight in pounds

N = number of legs

L = choker length in feet

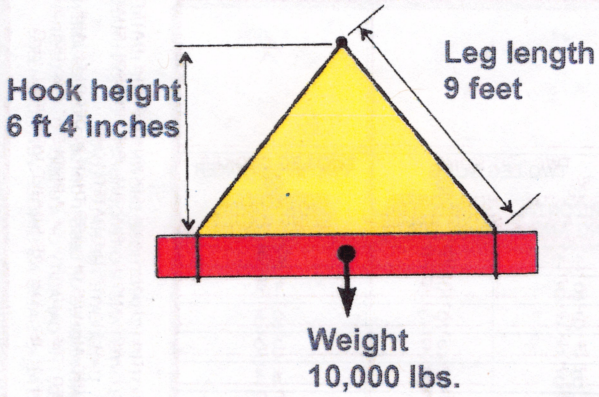
H = vertical height in feet



- The formula for hook back on chokers is more accurate and should be used rather than attempting to measure angles.
- The formula works for any number of sling legs, however it is best for rigs that have only two legs.
- When there are more than two legs it is difficult to determine whether or not each leg is carrying its share of the load.
- Inflexible loads typically have weight on only two legs.

Let's calculate sling stress together.

What is the stress per leg?



- Leg length = 9 ft. 0 in. = 108 inches
- Hook height = 6 ft. 4 in. = 76 inches
- 108" (L) ÷ 76" (H) = 1.42 (Factor)
- Net load = 10,000 lbs.
- 1.42 x 10,000 lbs. = 14,200 lbs.
- 14,200 ÷ 2 legs = *7,100 lbs. per leg*

Optional Exercise: Use the rigging resource on page 106 to determine the capacity in tons for each sling using wire rope, IWRC 6 x 19 and 6 x 37 class:

A. 3/4" sling basket - 30°

5.6

B. 5/8" sling double wrap choker

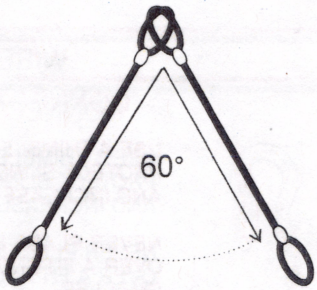
2.9

C. 1-1/8" sling single vertical hitch

12

D. 1" sling basket - 45°

13.7



H. 1-1/4" sling two leg bridle

26

F. 1-3/8" sling double wrap basket.

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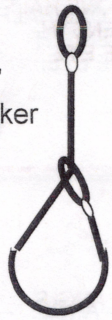
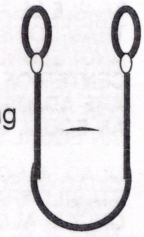


E. 1/2" Sling choker

1.9



G. 3/8" sling basket

2.8

Assume that the D/d ratio is 25/1 and the vertical angle is given.

WIRE ROPE SLING CAPACITIES - TONS (2000 LBS.) - FLEMISH EYE - ASME B30.9 5

BASED ON 6 X 19 AND 6 X 37 EIP STEEL, IWRC (FOR FIBER CORE DEDUCT APPROXIMATELY 15%) WITH DESIGN FACTOR OF 5

WIRE ROPE SIZE INCHES	SINGLE LEG (VERTICAL)	SINGLE CHOKER	TWO LEG SLING VERTICAL	TWO LEG SLING 60° HORIZONTAL SLING ANGLE	TWO LEG SLING 45° HORIZONTAL SLING ANGLE	TWO LEG CHOKER 60° HORIZONTAL SLING ANGLE
1/4	0.65	0.48	1.3	1.1	0.9	0.8
3/8	1.4	1.1	2.9	2.5	2.0	1.8
7/16	1.9	1.4	3.9	3.4	2.7	2.5
1/2	2.5	1.9	5.1	4.4	3.6	3.2
9/16	3.2	2.4	6.4	5.5	4.5	4.1
5/8	3.9	2.9	7.8	6.8	5.5	5.0
3/4	5.6	4.1	11.0	9.7	7.9	7.1
7/8	7.6	5.6	15.0	13.0	11.0	9.7
1	9.8	7.2	20.0	17.0	14.0	13.0
1-1/8	12.0	9.1	24.0	21.0	17.0	16.0
1-1/4	15.0	11.0	30.0	26.0	21.0	19.0

FOR SLING ANGLES OTHER THAN THOSE SHOWN, USE THE RATED LOAD FOR THE NEXT LOWER ANGLE OR A QUALIFIED PERSON SHALL CALCULATE THE RATED LOAD

HORIZONTAL SLING ANGLES OF LESS THAN 30 DEGREES ARE NOT RECOMMENDED. THE CAPACITY OF A BRIDLE AT A 30 DEGREE HORIZONTAL IS SAME AS SINGLE VERTICAL LEG.

RATED LOAD BASED ON PIN DIAMETER NO LARGER THAN ONE HALF THE NATURUAL EYE LENGTH OR NOT LESS THAN THE NOMINAL SLING DIAMETER
BASKET HITCH CAPACITY BASED ON MINIMUM D/d RATIO OF 25/1
FOR CHOKER HITCH, THE ANGLE OF CHOKE SHALL BE 120 DEGREES OR GREATER

WIRE ROPE SLING CONNECTIONS AND HITCHES 6

CONNECTION TO FITTINGS

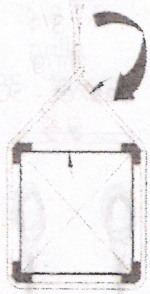
USE A THIMBLE TO PROTECT SLING AND INCREASE D/d

NEVER PLACE EYE OVER A FITTING SMALLER DIAMETER OR WIDTH THAN THE ROPE'S DIAMETER.

NEVER PLACE A SLING EYE OVER A FITTING WITH A DIAMETER OR WIDTH GREATER THAN ONE HALF THE LENGTH OF THE EYE.

CHOKER CAPACITY

A CHOKER HITCH HAS 75% OF THE CAPACITY OF A SINGLE LEG SLING ONLY IF THE ANGLE OF CHOKE IS 120 DEGREES OR GREATER. A CHOKE ANGLE LESS THAN 120 DEGREES CAN RESULT IN A CAPACITY AS LOW AS 40% OF THE SINGLE LEG.



BASKET HITCH CAPACITY

A BASKET HITCH HAS TWICE THE CAPACITY OF A SINGLE LEG ONLY IF D/d RATIO IS 25/1 AND THE LEGS ARE VERTICAL.

CAPACITY % OF ANGLE SINGLE LEG	
90	200 %
60	170 %
45	140 %
30	100 %

MULTIPLE LEG SLINGS

TRIPLE LEG SLINGS HAVE 50% MORE CAPACITY THAN DOUBLE LEG SLINGS (AT SAME SLING ANGLE) ONLY IF THE CENTER OF GRAVITY IS IN CENTER OF CONNECTION POINTS AND LEGS ARE ADJUSTED PROPERLY (THEY MUST HAVE AN EQUAL SHARE OF THE LOAD).

QUAD (4LEG) SLINGS OFFER IMPROVED STABILITY BUT PROVIDE INCREASED CAPACITY ONLY IF ALL LEGS SHARE AN EQUAL SHARE OF THE LOAD.